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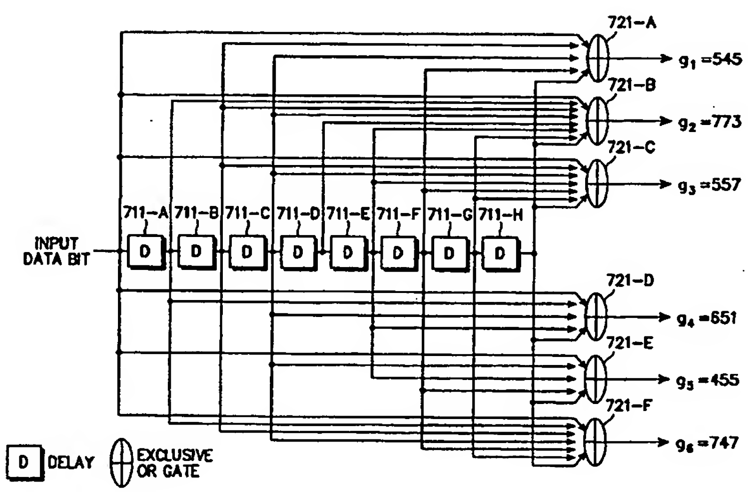

(57) Abstract

A device and method for generating and distributing convolutional codes such that performance degradation due to a bad link environment may be minimized during channel decoding in a CDMA communication system. The convolutional encoder encodes transmission data at a coding rate of R=1/6 and can be used for a channel encoder. Such a channel encoder can be used in both a DS-CDMA communication system and a multicarrier CDMA communication system. When the channel encoder is used in the multicarrier CDMA communication system, the symbols outputted from multiple constituent encoders for the channel encoder are distributed to multiple carrier channels according to a predetermined rule, and the constituent encoders for the channel encoder can minimize the performance degradation of the overall channel encoder even though an output of a particular constituent encoder is completely off at the transmission channel.

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DEVICE AND METHOD FOR GENERATING AND DISTRIBUTING CODED SYMBOLS IN CDMA COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a data transmission device and method for a CDMA communication system, and in particular, to a device and method for generating and distributing symbols capable of preventing degradation of a channel performance during data transmission.

2. Description of the Related Art

At present, code division multiple access (CDMA) communication systems are implemented based on the IS-95 standard. However, with the development of communication technology, subscribers to the communication services increase greatly in number. Therefore, there are proposed many methods for meeting the subscriber's increasing demands for the high quality service. An approach to such methods includes a method for improving a forward link structure.

For an improved forward link structure, there is a forward link fundamental channel designed for a third generation multicarrier CDMA system proposed in the TIA/EIA TR45.5 conference. A forward link structure for a multicarrier CDMA communication system is illustrated in FIG. 1.

Referring to FIG. 1, a channel encoder 10 encodes input data, and a rate matcher 20 repeats and punctures symbols output from the channel encoder 10. Here, the data input to the channel encoder 10 has a variable bit rate. The rate matcher 20 repeats and punctures the coded data bits (i.e., symbols) output from the channel encoder 10 so as to match symbol rates for the data having the variable bit rate. A channel interleaver 30 interleaves an output of the rate matcher 20. A block interleaver is typically used for the interleaver 30.

A long code generator 91 generates a long code which is identical to that used by the subscriber. The long code is a unique identification code for the subscriber. Thus, different long codes are assigned to the respective subscribers. A decimator 92 decimates the long code to match a rate of the long code to a rate of the symbols output from the interleaver 30. An adder 93 adds an output of the channel interleaver 30 and an output of the decimator 92. An exclusive OR gate is typically used for the adder 93.

A demultiplexer 40 sequentially multiplexes data output from the adder 93 to multiple carriers A, B and C. First to third binary-to-four level converters 51-53 convert signal levels of binary data output from the demultiplexer 40 by converting input data of "0" to "+1" and input data of "1" to "-1". First to third orthogonal modulators 61-63 encode data output from the first to third level converts 51-53 with corresponding Walsh codes, respectively. Here, the Walsh codes have a length of 256 bits. First to third spreaders 71-73 spread outputs of the first to third orthogonal modulators 61-63, respectively. Here, QPSK (Quadrature Phase Shift Keying) spreaders can be used for the spreaders 71-73. First to third attenuators (or gain controllers) 81-83 control gains of the spread signals output from the first to third spreaders 71-73 according to corresponding attenuation signals GA-GC, respectively. Here, the signals output from the first to third attenuators 81-83

become different carriers A, B and C.

In the forward link structure of FIG. 1, the channel encoder 10 having a coding rate of R=1/3 encodes the input data into 3 coded data bits (i.e., code words or symbols) per bit. Such coded data bits are demultiplexed to the three carriers A, B and C after rate matching and channel interleaving.

The multicarrier CDMA communication system of FIG. 1 can be modified to a single carrier CDMA communication system by removing the demultiplexer 40 and using only a set of the level converter, the orthogonal modúlator, the spreader and the attenuator.

FIG. 2 is a detailed diagram illustrating the channel encoder 10, the rate matcher 20 and the channel interleaver 30. In FIG. 2, data of a first rate is composed of 172 bits (full rate) per 20ms frame; data of a second rate is composed of 80 bits (1/2 rate) per 20ms frame; data of a third rate is composed of 40 bits (1/4 rate) per 20ms frame; and data of a fourth rate is composed of 16 bits (1/8 rate) per 20ms frame.

Referring to FIG. 2, first to fourth CRC generators 111-114 generate CRC bits corresponding to the respective input data having different rates and add the generated CRC bits to the input data. Specifically, 12-bit CRC is added to the 172-bit data of the first rate; 8-bit CRC is added to the 80-bit data of the second rate; 6-bit CRC is added to the 40-bit data of the third rate; and 6-bit CRC is added to the 16-bit data of the fourth rate.

First to fourth tail bit generators 121-124 add 8 tail bits to the CRC-added data, respectively. Therefore, the first tail bit generator 121 outputs 192 bits; the

second tail bit generator 122 outputs 96 bits; the third tail bit generator 123 outputs 54 bits; and the fourth tail bit generator 124 outputs 30 bits.

First to fourth encoders 11-14 encode data output from the first to fourth tail bit generators 121-124, respectively. Here, a convolutional encoder having a constraint length of K=9 and a coding rate of R=1/3 can be used for the encoders 11-14. In this case, the first encoder 11 encodes the 192-bit data output from the first tail bit generator 121 into 576 symbols of full rate; the second encoder 12 encodes the 96-bit data output from the second tail bit generator 122 into 288 symbols of 1/2 rate; the third encoder 13 encodes the 54-bit data output from the third tail bit generator 123 into 162 symbols of about 1/4 rate; and the fourth encoder 14 encodes the 30-bit data output from the fourth tail bit generator 124 into 90 symbols of about 1/8 rate.

The rate matcher 20 includes repeaters 22-24 and symbol deletion devices 27-28. The repeaters 22-24 repeat symbols output from the second to fourth encoders 12-14 predetermined times, respectively, so as to increase output symbol rates thereof to the full rate. The symbol deletion devices 27 and 28 delete symbols output from the repeaters 23 and 24, which exceed the symbols of the full rate in number. Since the second encoder 12 outputs 288 symbols which is 1/2 the 576 symbols output from the first encoder 11, the second repeater 22 repeats the received 288 symbols two times to output 576 symbols. Further, since the third encoder 13 outputs 162 symbols which is about 1/4 the 576 symbols output from the first encoder 11, the third repeater 23 repeats the received 162 symbols four times to output 648 symbols, which exceeds the 576 symbols of full rate in number. To match the symbol rate to the full rate, the symbol deletion device 27 deletes every ninth symbols to output 576 symbols of full rate. In addition, since the fourth encoder 14 outputs 90 symbols which is about 1/8 the 576 symbols output from the

first encoder 11, the fourth repeater 24 repeats the received 90 symbols eight times to output 720 symbols, which exceeds the 576 symbols of full rate in number. To match the symbol rate to the full rate, the symbol deletion device 28 deletes every fifth symbols to output 576 symbols of full rate.

First to fourth channel interleavers 31-34 interleave the symbols of full rate output from the first encoder 11, the second repeater 22, the symbol deletion device 27 and the symbol deletion device 28, respectively.

Forward error correction (FEC) is used to maintain a sufficiently low bit error rate (BER) of a mobile station for a channel having a low signal-to-noise ratio (SNR) by providing a channel coding gain. The forward link for the multicarrier communication system can share the same frequency band with the forward link for the existing IS-95 system in an overlay method. However, this overlay method raises the follow problems.

In the overlay method, three forward link carriers for the multicarrier system are overlaid on three 1.25MHz bands used in the existing IS-95 CDMA system. FIG. 3 illustrates transmission power levels, by the respective bands, of base stations for the IS-95 system and the multicarrier system. In the overlay method, since the frequency bands for the multicarrier system are overlaid on the frequency bands for the existing IS-95 system, the transmission power or channel capacity is shared between the IS-95 base station and the multicarrier base station at the same frequency band. In the case where the transmission power is shared between the two systems, the transmission power is first allocated for the IS-95 channel which mainly supports a voice service and then, the maximum transmission power permissible to the respective carriers for the multicarrier CDMA system is determined. Here, the maximum transmission power cannot exceed a predetermine

power level, because the base station has a limited transmission power. Further, when the base station transmits data too many subscribers, interference among the subscribers increases resulting in an increase in noises. FIG. 3 illustrates the state where the IS-95 base station and the multicarrier base station allocate almost equal transmission powers at the respective 1.25MHz frequency bands.

However, the IS-95 channels of 1.25MHz frequency bands have a different transmission power according to a change in the number of the subscribers in service and a change in voice activity of the subscribers. FIGs. 4 and 5 illustrate the situations where the transmission power allocated for the multicarrier base station decreases at some carriers, as the transmission power allocated for the IS-95 base station increases rapidly at the corresponding frequency bands due to an increase in number of the IS-95 subscribers. As a result, sufficient transmission power cannot not be allocated for one or more of the multiple carriers, so that the SNRs are different according to the carriers at the receiver. Accordingly, a signal received at a carrier having the low SNR increases in a bit error rate (BER). That is, when the IS-95 subscriber increases in number and the voice activity is relatively high, a signal transmitted via a carrier overlaid on the corresponding frequency band increases in the BER, resulting in a decreased system capacity and an increased interference among the IS-95 subscribers. That is, the overlay method may cause a reduction in capacity of the multicarrier system and an increase in interference among the IS-95 subscribers.

In the multicarrier system, the respective carriers may have independent transmission powers as illustrated in FIGs. 4 and 5. In the light of the performance, FIG. 4 shows the power distribution which is similar to the case where a R=1/2 channel encoder is used, and FIG. 5 shows the power distribution which is worse than the case where the channel encoder is not used. In these cases, one or two of

the three coded bits (i.e., symbols) for an input data bit may not be transmitted, causing a degradation of the system performance.

Moreover, even in a direct spreading CDMA communication system using a single carrier, weight distribution of the symbols generated by channel encoding is poor, which may cause a performance degradation of channel decoding.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to provide a channel encoding device and method capable of generating coded data having a good channel coding performance in a CDMA communication system.

It is another object of the present invention to provide a channel encoding device and method capable of generating channel coded data having a good channel coding performance and effectively distributing the generated channel-coded data to respective carriers in a multicarrier CDMA communication system.

It is further another object of the present invention to provide a channel transmission device and method for distributing generated symbols to carriers such that an influence of symbols damaged during transmission can be minimized in a multicarrier CDMA communication system.

It is still another object of the present invention to provide an R=1/6 convolutional encoding device and method capable of increasing a channel performance in a channel transmitter for a CDMA communication system.

To achieve the above object, there is provided a communication system using

at least two carriers. The communication system includes a channel encoder for encoding data, a channel controller for generating a control signal for transmitting channel coded symbols such that decoding can be performed using data received via at least one carrier, and a symbol distributer for assigning the channel coded symbols to at least two carriers.

Also, there is provided a channel encoding device having: a plurality of delays for delaying an input data bit to generate first to eight delayed data bits; a first operator for exclusively ORing the input data bit and the third, fifth, sixth, seventh and eighth delayed data bits to generate a first symbol; a second operator for exclusively ORing the input data bit and the first, second, third, fifth, sixth and eighth delayed data bits to generate a second symbol; a third operator for exclusively ORing the input data bit and the second, third, fifth and eighth delayed data bits to generate a third symbol; a fourth operator for exclusively ORing the input data bit and the first, fourth, fifth, sixth, seventh and eighth delayed data bits to generate a fourth symbol; a fifth operator for exclusively ORing the input data bit and the first, fourth, sixth and eighth delayed data bits to generate a fifth symbol; and a sixth operator for exclusively ORing the input data bit and the first, second, fourth, sixth, seventh and eighth delayed data bits to generate a sixth symbol.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become more apparent from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagram illustrating a forward link structure for a conventional multicarrier CDMA communication system;

FIG. 2 is a diagram illustrating a fundamental channel structure for a forward

link of FIG. 1;

FIG. 3 is a diagram illustrating transmission power distribution of IS-95 channel bands and multicarrier channel bands in the case where the multicarrier channels are overlaid on the IS-95 channels at the same frequency bands;

FIG. 4 is a diagram illustrating a state where the transmission power for one of multiple carriers is decreased when a transmission power for a corresponding IS-95 channel is increased, due to a limitation in transmission power or transmission capacity of the system;

FIG. 5 is a diagram illustrating a state where the transmission powers for two of multiple carriers are decreased when transmission powers for corresponding IS-95 channels are increased, due to a limitation in transmission power or transmission capacity of the system;

FIG. 6 is a diagram illustrating a scheme for generating convolutional codes of a symbol rate 1/6, employing a channel encoder and a symbol distributer according to an embodiment of the present invention;

FIG. 7 is a detailed diagram illustrating an R=1/6 convolutional encoder of FIG. 6;

FIG. 8 is a detailed diagram illustrating a symbol distributer of FIG. 6;

FIG. 9 is a diagram illustrating a transmission scheme for a forward link using a channel encoder and a symbol distributer according to an embodiment of the present invention;

FIG. 10 is a simulation diagram illustrating a performance comparison among R=1/3 convolutional codes according to an embodiment of the present invention;

FIG. 11 is a simulation diagram illustrating a worst performance comparison among R=1/2 convolutional codes using generator polynomials of a convolutional encoder having a coding rate of R=1/3;

FIG. 12 is a simulation diagram illustrating a performance comparison

among R=1/2 constraint codes for an R=1/6 convolutional code; and

FIG. 13 is a simulation diagram illustrating a worst performance comparison among R=1/2 constraint codes using an R=1/6 convolutional encoder with a highest performance.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will be described hereinbelow with reference to the accompanying drawings. In the following description, well known functions or constructions are not described in detail since they would obscure the invention in unnecessary detail.

A term "symbol" as used herein refers to a coded data bit output from an encoder. For convenience of explanation, it is assumed that the multicarrier communication system is a three-carrier CDMA communication system using three carriers.

In a communication system supporting both the IS-95 system and the multicarrier system, wherein transmission signals of the two different systems are overlaid at the same frequence bands, coded symbols are distributed such that a performance degradation may be minimized during decoding of the damaged symbols, and then the distributed coded bits are assigned to the respective carriers. Thus, even if one of the carriers has interference during reception, it is possible to perform decoding for only the coded bits transmitted via the other carriers, thereby improving the system performance.

Moreover, in the forward link, an R=1/6 convolutional code can be used for a channel encoder. Therefore, when the channel encoder generates R=1/6

convolutional codes, it is very difficult to find R=1/6 convolutional codes having a good decoding performance. Accordingly, the present invention is directed to generating R=1/6 convolutional codes with a good decoding performance and distributing the generated convolutional codes to multiple carriers. The R=/16 convolutional codes generated according to the present invention have a good performance in both a multicarrier CDMA communication system and a DS-CDMA communication system.

A description will now be made regarding an operation of generating symbols for maximizing a channel performance and distributing the generated symbols in a CDMA communication system according to an embodiment of the present invention. For convenience, the present invention will be described hereinafter with reference to a multicarrier CDMA communication system.

First, reference will be made to R=1/6 convolutional codes for a multicarrier CDMA communication system using three carriers. FIG. 6 illustrates a convolutional encoder and a symbol distributer according to an embodiment of the present invention.

Referring to FIG. 6, a convolutional encoder 601 encodes one input data bit into six symbols which are allocated to three carriers A, B and C. For symbol allocation, a symbol distributer 602 uniformly distributes the six input bits to the three carriers by two bits. The symbol distributer 602 distributes the symbols output from the convolutional encoder 601, taking into consideration how many carriers are damaged out of the three carriers. By using this symbol distribution method, even though one or two out of the three carriers are damaged, performance degradation in channel decoding can be minimized.

A description will now be made as to a method of designing the symbol distributer 602. A bit error rate (BER) after channel decoding depends on a damaged portion for the symbols coded by a channel encoder. Therefore, even though the coded symbols are damaged, the symbols located at the minimized performance degraded portion are uniformly distributed to the carriers. Accordingly, even though the symbols for a certain channel are all damaged, an increase in the BER after channel decoding can be minimized.

In addition, during transmission, the symbols output from a constituent encoder in the channel encoder are distributed to the carriers; during decoding, a constituent decoder in a channel decoder is selected such that the BER can be low even though the symbols for a certain carrier are all damaged.

Selection of the constituent decoder in the channel decoder is made in the following process. First, reference will be made to a convolutional code having a constraint length of K=9 and a rate of R=1/3. In the following descriptions, generator polynomials gi are represented by octal number. The convolutional code with K=9 and R=1/3 has a free distance of d_{free}=18. It is noted that there exists 5685 sets, when search is made for convolutional codes having K=9, R=1/3 and d_{free}=18, by changing generator polynomials g_1, g_2 and g_3. Here, only non-catastrophic codes are selected. In addition, it is necessary to prevent the performance degradation even though a certain carrier is completely off, providing for application to the multicarrier system. From this point of view, it is preferable <u>to</u> maximize the free distance.

For a reference code for performance comparison, a convolutional code of (g_1, g_2, g_3) = (557, 663, 711) is used which is used in the existing IS-95 system. In the IS-95 system, a free distance of the convolutional code is d_{free}=18, and free

distances between constituent codes are $d_{free}(g_{557},g_{663})=9$, $d_{free}(g_{557},g_{711})=11$, and $d_{free}(g_{663},g_{711})=10$. A performance of a convolutional code can be predicted using a BER upper limit formula, which is determined by a transfer function.

For the IS-95 system, a transfer function of a convolutional code is $T(D,I)|_{I=1} = 5D^{18}+7D^{20}+O(D^{21})$, and a BER upper limit formula is $(\partial/\partial I)T(D,I)|_{I=1} = 11D^{18}+32D^{20}+O(D^{21})$. When the convolutional code for the IS-95 system is view in the light of a constituent code, a catastrophic error propagation occurs at a combination of generator polynomials g_1 and g_2. Therefore, when the convolutional codes for the IS-95 system are used for the multicarrier system, it is necessary to appropriately use interleaving and puncturing. Since the IS-95 convolutional codes have the catastrophic error propagation in the light of the constituent codes, it is necessary to search for new convolutional codes suitable for the multicarrier system. For K=9, $d_{free}(g_i,g_j)\leq 12$. It is found from a complete computer search that there is no convolutional code for which a free distance between constituent codes is always 12. Therefore, there are only eight codes having the free distance of $d_{free}(g_i,g_j)\geq 11$. Here, not only the codes but also the constituent codes are non-catastrophic. Since a first term of the BER upper limit formula is most influential, first and eighth codes can be considered to be most optimal codes. Here, since the pairs of first and eighth codes; second and seventh codes; third and fourth codes; and fifth and sixth codes are in reciprocal relation, they are the same codes essentially. Therefore, there exist only four codes.

Table 1 is given to explain a characteristic of a convolutional encoder with K=9 and R=1/3.

[TABLE 1]

No	Generator Polynomial		Remarks
1	467	Free Distance between Constituent Codes	$d_{12}=11$, $d_{13}=11$, $d_{23}=12$
	543	Transfer Function, $T(D,I)\|_{I=1}$	$4D^{18}+12D^{20}+O(D^{21})$
	765	BER Upper Limit Formula	$9D^{18}+54D^{20}+O(D^{21})$
2	547	Free Distance between Constituent Codes	$d_{12}=11$, $d_{13}=11$, $d_{23}=12$
	643	Transfer Function, $T(D,I)\|_{I=1}$	$6D^{18}+9D^{20}+O(D^{21})$
	765	BER Upper Limit Formula	$19D^{18}+33D^{20}+O(D^{21})$
3	453	Free Distance between Constituent Codes	$d_{12}=11$, $d_{13}=12$, $d_{23}=11$
	665	Transfer Function, $T(D,I)\|_{I=1}$	$5D^{18}+7D^{20}+O(D^{21})$
	771	BER Upper Limit Formula	$13D^{18}+31D^{20}+O(D^{21})$
4	477	Free Distance between Constituent Codes	$d_{12}=11$, $d_{13}=12$, $d_{23}=11$
	533	Transfer Function, $T(D,I)\|_{I=1}$	$5D^{18}+7D^{20}+O(D^{21})$
	651	BER Upper Limit Formula	$13D^{18}+31D^{20}+O(D^{21})$
5	561	Free Distance between Constituent Codes	$d_{12}=11$, $d_{13}=12$, $d_{23}=11$
	647	Transfer Function, $T(D,I)\|_{I=1}$	$5D^{18}+7D^{20}+O(D^{21})$
	753	BER Upper Limit Formula	$13D^{18}+31D^{20}+O(D^{21})$
6	435	Free Distance between Constituent Codes	$d_{12}=12$, $d_{13}=11$, $d_{23}=11$
	657	Transfer Function, $T(D,I)\|_{I=1}$	$5D^{18}+7D^{20}+O(D^{21})$
	713	BER Upper Limit Formula	$13D^{18}+31D^{20}+O(D^{21})$

7	537	Free Distance between Constituent Codes	$d_{12}=12$, $d_{13}=11$, $d_{23}=11$
	613	Transfer Function, $T(D,I)\|_{I=1}$	$6D^{18}+9D^{20}+O(D^{21})$
	715	BER Upper Limit Formula	$19D^{18}+33D^{20}+O(D^{21})$
8	537	Free Distance between Constituent Codes	$d_{12}=12$, $d_{13}=11$, $d_{23}=11$
	615	Transfer Function, $T(D,I)\|_{I=1}$	$4D^{18}+12D^{20}+O(D^{21})$
	731	BER Upper Limit Formula	$9D^{18}+54D^{20}+O(D^{21})$

In Table 1, d_{12} in a first term means $d_{(467,543)}$ and hereinafter, used in the same meaning. For information, when the codes are compared with the IS-95 codes in the light of the first term of the BER upper limit formula, the first and eighth codes are superior in performance to the IS-95 codes, the third, fourth, fifth and sixth codes are similar in performance to the IS-95 codes, and the second and seventh codes are inferior in performance to the IS-95 codes. Therefore, it is preferable to use the eighth (or first) code.

In the meantime, there exist four or more codes whose the free distances among the constituent codes are 12, 12 and 10; among these codes, a generator polynomial for a superior code in the light of the first term of the BER upper limit formula is $(g_1,g_2,g_3) = (515, 567, 677)$. Shown in FIG. 10 is the simulation result for performances of the convolutional code with R=1/3 in a AWGN (Additive White Gaussian Noise) environment in the case where the multicarrier (three-carrier) system has an optimal performance without damage of the respective carriers. In the following descriptions, the simulations of FIGs. 11-13 are all performed in the AWGN environment. <Case 1> represents a R=1/3 convolutional code for an existing IS-95 system, and <Case 2> and <Case 3> represent a R=1/3 convolutional code searched for in the above method.

<Case 1> IS-95 (g_1=557, g_2=663, g_3=711) → d_{free}=18

<Case 2> g_1=731, g_2=615, g_3=537 → d_{free}=18

$d_{free}(g_1,g_2)$=11, $d_{free}(g_1,g_3)$=11, $d_{free}(g_2,g_3)$=12

<Case 3> g_1=515, g_2=567, g_3=677 → d_{free}=18

$d_{free}(g_1,g_2)$=11, $d_{free}(g_1,g_3)$=12, $d_{free}(g_2,g_3)$=10

A description will now be made regarding the case where the R=1/3 convolutional code is applied to the three-carrier system and a certain one of the three carriers is damaged (or lost). Although the original coding rate is 1/3, the loss of one carrier causes the coding rate to be equal to 1/2. Therefore, shown in FIG. 11 is the simulation results for the 1/2 convolutional codes using the generator polynomials for the 1/3 convolutional codes. In FIG. 11, the respective conditions can be explained by the following <Case 1> through <Case 4>. FIG. 11 illustrates the worst performance graph for the R=1/2 convolutional codes using the generator polynomials for the R=1/3 convolutional code.

<Case 1> Optimal 1/2 convolutional code → g_1=561, g_2=753, $d_{free}(g_1,g_2)$=12

<Case 2> the worst performance, g_1=557, g_2=711 out of three R=1/2 convolutional codes using the generator polynomial (557, 663, 711) for a 1/3 convolutional code used for the IS-95 system → catastrophic error propagation occurs

<Case 3> the worst performance, g_1=731, g_2=615 ($d_{free}(g_1,g_2)$=11) for a R=1/2 convolutional code using the generator polynomial (731, 615, 537) for a R=1/3 convolutional code

<Case 4> the worst performance, g_1=567, g_2=677 ($d_{free}(g_1,g_2)$=10) for a R=1/2 convolutional code using the generator polynomial (515, 567, 677) for a R=1/3 convolutional code

When one carrier is damaged in a three-carrier system using an R=1/3 convolutional code, the coding rate becomes to be equal to R=1/2. In this case, a symbol distribution method for the symbol distributer is found by appropriately distributing the original R=1/3 convolutional codes to the three carriers using the following symbol deleting matrixes, so as to minimize the performance degradation even though the coding rate becomes R=1/2. In the simplest method, the following two symbol deleting matrixes are generated. In the following symbol deleting matrixes, "0" means the case where a carrier to which the corresponding symbol is provided is damaged, and "1" means the case where the carrier to which the corresponding symbol is provided is not damaged. That is, this means the case that the symbols corresponding to "0" are all allocated to a certain carrier, which is damaged during transmission. Therefore, one of the following various patterns of the symbol deleting matrix is selected, which minimizes the performance degradation even though one carrier is damaged, and the symbol distributer 602 provides the symbols to the respective carriers using the selected pattern. The followings are symbol deleting matrixes for finding a pattern used for the symbol distributer 602.

$$D_1 = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

$$D_2 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

Further, an m-sequence of length=8 is generated over a two-stage GF(3) using an m-sequence. For a ninth convolutional code, a sequence {1,2,0,2,2,1,0,1,2}

is generated and then, the following symbol deleting matrix D_3 is generated using the sequence.

$$D_3 = \begin{bmatrix} 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

Further, the following symbol deleting matrixes D_4 and D_5 are generated by changing the row of the symbol deleting matrix D_3.

$$D_4 = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$$

$$D_5 = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \end{bmatrix}$$

In addition, a sequence {2,1,0,1,1,0,1,2,1,0,0,0,2,1,2} is obtained by generating 15 random numbers over GF(3) using a random number, and the following symbol deleting matrix D_6 is created using the above sequence.

$$D_6 = \begin{bmatrix} 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Also, the following symbol deleting matrixes D_7 and D_8 are generated by changing the rows as in the method using the m-sequence.

$$D_7 = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \end{bmatrix}$$

$$D_8 = \begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Next, a description will be made regarding a convolutional code having a symbol rate of 1/6. A K=9, R=1/6 convolutional code has a free distance of $d_{free}=37$. In searching for the convolutional codes having a free distance of $d_{free}=37$ by randomly changing the generator polynomials $g_1, g_2, \ldots, g_6$, the following conditions should be satisfied.

First, it should be a R=1/6 convolutional code with a good decoding performance.

Second, it should be a R=1/4 convolutional code with a good decoding performance which has generator polynomials (g_1,g_2,g_3,g_4), (g_1,g_2,g_5,g_6) and (g_3,g_4,g_5,g_6), considering the case that one of three carriers is damaged in the three-carrier system.

Third, it should be a 1/2 convolutional code with a good decoding performance which has generator polynomials (g_1,g_2), (g_3,g_4) and (g_5,g_6), considering the case that two of three carriers are damaged in the three-carrier system.

In the second and third conditions out of the above three conditions, the performance degradation is minimized even though one or two of the three carriers

are completely off, providing for the multicarrier system in which six output bits of the covolutional code are allocated to three carriers by two bits. From this point of view, it is preferable that the R=1/4 convolutional code and the R=1/2 convolutional code have the maximum free distance.

A method of searching for a R=1/2 convolutional code satisfying the third condition becomes apparent from the following description. There exist 35 non-catastrophic convolutional codes with R=1/2, K=9 and d_{free}=12. An upper limit formula for the BER is give as follows, and a coefficient c_{12} of the most important term D^{12} in determining the BER ranges from 33 to 123.

$$(\partial/\partial I)T(D,I)|_{I=1}=c_{12}D^{12} + c_{13}D^{13} + \ldots$$

First, for the R=1/6 convolutional codes, there exist 180 R=1/6 convolutional codes with d_{free}=37, satisfying the third condition. It is assumed that $d_{free}(g_{2i-1},g_{2i})$=12. Here, there exist 58 convolutional codes in which the first term of the BER upper limit formula for the R=1/6 convolutional code has a coefficient of c_{37}=1. The following are the R=1/6 convolutional codes selected among the 58 convolutional codes after performance verification.

1) (457, 755, 551, 637, 523, 727): $c_{38} = 4$ (NO=1)
2) (457, 755, 551, 637, 625, 727): $c_{38} = 4$ (NO=3)
3) (457, 755, 455, 763, 625, 727): $c_{38} = 4$ (NO=5)
4) (515, 677, 453, 755, 551, 717): $c_{38} = 6$ (NO=7)
5) (515, 677, 453, 755, 551, 717): $c_{38} = 6$ (NO=9)
6) (515, 677, 557, 651, 455, 747): $c_{38} = 6$ (NO=11)
7) (457, 755, 465, 753, 551, 637): $c_{38} = 6$ (NO=13)
8) (515, 677, 551, 717, 531, 657): $c_{38} = 8$ (NO=27)

9) (515, 677, 455, 747, 531, 657): $c_{38} = 8$ (NO=29)

10) (453, 755, 557, 751, 455, 747): $c_{38} = 10$ (NO=31)

11) (545, 773, 557, 651, 551, 717): $c_{38} = 12$ (NO=51)

12) (453, 755, 457, 755, 455, 747): $c_{38} = 20$ (NO=57)

The following are 5 R=1/6 convolutional codes with a good decoding performance selected among the 12 performance-verified 1/6 convolutional codes.

1) (457, 755, 551, 637, 523, 727): $c_{38} = 4$ (NO=1)

2) (515, 677, 453, 755, 551, 717): $c_{38} = 6$ (NO=7)

3) (545, 773, 557, 651, 455, 747): $c_{38} = 6$ (NO=8)

4) (515, 677, 557, 651, 455, 747): $c_{38} = 6$ (NO=11)

5) (515, 677, 455, 747, 531, 657): $c_{38} = 8$ (NO=29)

A performance of the R=1/2 convolutional codes using five generator polynomials for the R=1/6 convolutional code are verified, and further, a performance of the R=1/4 convolutional codes using five generator polynomials for the R=1/6 convolutional code are verified. First, a transfer function for the R=1/2 convolutional codes will be described with reference to Table 2 in which the generator polynomials are represented by octal number.

[TABLE 2]

No	1/2 Generator Polynomial	BER Upper Limit Formula, Coeff c_{12}, c_{13}, c_{14}
1	435, 657	(33, 0, 281)
2	561, 753	(33, 0, 281)
3	515, 677	(38, 106, 238)

4	545, 773	(38, 106, 238)
5	463, 755	(38, 0, 274)
6	557, 631	(38, 0, 274)
7	557, 751	(40, 33, 196)
8	457, 755	(40, 33, 196)
9	453, 755	(40, 0, 271)
10	557, 651	(40, 0, 271)
11	471, 673	(50, 0, 298)
12	537, 615	(50, 0, 360)
13	543, 765	(50, 0, 360)
14	455, 747	(50, 0, 395)
15	551, 717	(50, 0, 395)
16	465, 753	(52, 0, 287)
17	531, 657	(52, 0, 287)
18	455, 763	(52, 0, 339)
19	551, 637	(52, 0, 339)
20	561, 735	(57, 0, 355)
21	435, 567	(57, 0, 355)
22	561, 755	(57, 0, 390)
23	435, 557	(57, 0, 390)

24	465, 771	(58, 0, 321)
25	477, 531	(58, 0, 321)
26	537, 613	(67, 0, 472)
27	643, 765	(67, 0, 472)
28	523, 727	(68, 0, 349)
29	625, 727	(68, 0, 349)
30	523, 755	(68, 0, 363)
31	557, 625	(68, 0, 363)
32	453, 771	(70, 0, 496)
33	477, 651	(70, 0, 496)
34	515, 567	(123, 0, 589)
35	545, 735	(123, 0, 589)

A R=1/2 convolutional code with the highest performance is searched for by verifying the performances of the respective R=1/2 convolutional codes in Table 2. In addition, performances of the R=1/2 convolutional codes are compared with performances of the optimal R=1/2 convolutional code used for the IS-95 system.

<Case 1> generator polynomial → $(435, 657)_8$, NO=1, c_{12}=33

<case 2> generator polynomial → $(561, 753)_8$, NO=2, c_{12}=33, an optimal R=1/2 convolutional code used for the IS-95 standard

<Case 3> generator polynomial → $(557, 751)_8$, NO=7, c_{12}=40

<Case 4> generator polynomial → $(453, 755)_8$, NO=9, c_{12}=40

<Case 5> generator polynomial → $(471, 673)_8$, NO=11, c_{12}=50

<Case 6> generator polynomial → $(531, 657)_8$, NO=17, c_{12}=52

<Case 7> generator polynomial → $(561, 755)_8$, NO=22, c_{12}=57

<Case 8> generator polynomial → $(465, 771)_8$, NO=24, c_{12}=58

A performance comparison among the respective cases is shown in FIG. 12. FIG. 12 illustrates a performance comparison among R=1/2 constituent codes for the R=1/6 convolutional code. It is noted that the R=1/2 constituent codes for the R=1/6 convolutional code are similar in performance to the optimal R=1/2 convolutional code.

Table 3 illustrates transfer functions for the R=1/6 convolutional codes.

[TABLE 3]

No	1/6 Generator Polynomial (Octal Number)	1/6 BER coeff. c_{37},c_{38},c_{39}	1/2 BER coeff. c_{12} (1,2; 3,4; 5,6)	1/4 BER coeff. c_{24} (1234;1256;3456)
1	457 755 551 637 523 727	-149	-405268	-825
2	557 751 455 763 625 727	-149	-405268	-825
3	457 755 551 637 625 727	-149	-405268	-865
4	557 751 455 763 523 727	-149	-405268	-865
5	457 755 455 763 625 727	-149	-405268	-1465
6	557 751 551 637 523 727	-149	-405268	-1465
7	515 677 453 755 551 717	-169	-384050	-421
8	545 773 557 651 455 747	-169	-384050	-421

9	515 677 557 651 551 717	-1612	-384050	-421
10	545 773 453 755 455 747	-1612	-384050	-421
11	515 677 557 651 455 747	-1612	-384050	-481
12	545 773 453 755 551 717	-1612	-384050	-481
13	457 755 465 753 551 637	-1612	-405252	-685
14	457 755 531 657 551 637	-1612	-405252	-685
15	557 751 455 763 465 753	-1612	-405252	-865
16	557 751 455 763 531 657	-1612	-405252	-865
17	557 751 465 753 551 637	-1612	-405252	-6145
18	557 751 531 657 551 637	-1612	-405252	-6145
19	457 755 455 763 465 753	-1612	-405252	-1465
20	457 755 455 763 531 657	-1612	-405252	-1465
21	557 751 455 763 515 567	-169	-4052123	-861
22	457 755 551 637 545 735	-169	-4052123	-861
23	457 755 551 637 515 567	-169	-4052123	-881
24	557 751 455 763 545 735	-169	-4052123	-881
25	557 751 551 637 515 567	-169	-4052123	-1461
26	457 755 455 763 545 735	-169	-4052123	-1461
27	515 677 551 717 531 657	-186	-385052	-264
28	545 773 455 747 465 753	-186	-385052	-264

29	515 677 455 747 531 657	-186	-385052	-864
30	545 773 551 717 465 753	-186	-385052	-864
31	453 755 557 751 455 747	-11015	-404050	-416
32	457 755 557 651 551 717	-11015	-404050	-461
33	453 755 557 751 551 717	-11015	-404050	-4112
34	457 755 557 651 455 747	-11015	-404050	-4111
35	453 755 457 755 551 717	-11015	-404050	-1416
36	557 651 557 751 455 747	-11015	-404050	-1416
37	457 755 551 637 557 625	-1109	-405268	-8211
38	557 751 455 763 523 755	-1109	-405268	-8211
39	457 755 455 763 523 727	-1109	-405268	-1425
40	457 755 455 763 557 625	-1109	-405268	-1425
41	557 751 551 637 523 755	-1109	-405268	-1425
42	557 751 551 637 625 727	-1109	-405268	-1425
43	457 755 551 637 523 755	-1109	-405268	-8145
44	557 751 455 763 557 625	-1109	-405268	-8145
45	545 773 455 763 515 567	-1106	-3852123	-861
46	545 773 551 637 515 567	-1106	-3852123	-861
47	515 677 455 763 545 735	-1106	-3852123	-861
48	515 677 551 637 545 735	-1106	-3852123	-861

49	515 677 551 637 515 567	-1106	-3852123	-8181
50	545 773 455 763 545 735	-1106	-3852123	-8181
51	545 773 557 651 551 717	-1129	-384050	-481
52	515 677 453 755 455 747	-1129	-384050	-481
53	457 755 455 763 515 567	-1129	-4052123	-1481
54	557 751 551 637 545 735	-1129	-4052123	-1481
55	515 677 455 763 515 567	-1166	-3852123	-8181
56	545 773 551 637 545 735	-1166	-3852123	-8181
57	453 755 457 755 455 747	-12015	-404050	-1412
58	557 651 557 751 551 717	-12015	-404050	-1412

The worst performances of the R=1/2 constituent codes using 5 R=1/6 convolutional codes with the good decoding performance are as follows, with reference to Table 3.

<Case 1> the worst performance of a R=1/6 convolutional code (NO=1) having generator polynomials of $(457, 755, 551, 637, 523, 727)_8 \rightarrow (523, 727)_8$, $c_{12} = 68$

<Case 2> the worst performance of a R=1/6 convolutional code (NO=7) having generator polynomials of $(515, 677, 453, 755, 551, 717)_8 \rightarrow (515, 677)_8$, $c_{12} = 38$

<Case 3> the worst performance of a R=1/6 convolutional code (NO=8) having generator polynomials of $(545, 773, 557, 651, 455, 747)_8 \rightarrow (545, 773)_8$, $c_{12} = 38$

<Case 4> the worst performance of a R=1/6 convolutional code (NO=11) having generator polynomials of $(551, 677, 557, 651, 455, 747)_8 \rightarrow (551, 677)_8$, $c_{12} = 38$

<Case 5> the worst performance of a R=1/6 convolutional code (NO=29) having generator polynomials of $(515, 677, 455, 747, 531, 657)_8 \rightarrow (515, 677)_8$, $c_{12} = 38$

The worst performances for the R=1/4 constituent codes are as follows using the R=1/6 convolutional codes whose performances are verified for the R=1/2 constituent codes.

<Case 1> the worst performance of a R=1/6 convolutional code (NO=1) having generator polynomials of $(457, 755, 551, 637, 523, 727)_8 \rightarrow (551, 637, 523, 727)_8$, $c_{24} = 5$

<Case 2> the worst performance of a R=1/6 convolutional code (NO=7) having generator polynomials of $(515, 677, 453, 755, 551, 717)_8 \rightarrow (515, 677, 551, 717)_8$, $c_{24} = 2$

<Case 3> the worst performance of a R=1/6 convolutional code (NO=8) having generator polynomials of $(545, 773, 557, 651, 455, 747)_8 \rightarrow (545, 773, 455, 747)_8$, $c_{24} = 2$

<Case 4> the worst performance of a R=1/6 convolutional code (NO=11) having generator polynomials of $(551, 677, 557, 651, 455, 747)_8 \rightarrow (551, 677, 557, 651)_8$, $c_{24} = 4$

<Case 5> the worst performance of a R=1/6 convolutional code (NO=29) having generator polynomials of $(515, 677, 455, 747, 531, 657)_8 \rightarrow (515, 677, 531, 657)_8$, $c_{24} = 6$

FIG. 13 illustrates a comparison among the worst performances of R=1/2

constituent codes using R=1/6 convolutional code with the highest performance.

The following are two R=1/6 convolutional codes with the good decoding performance, selected among the R=1/6 convolutional codes whose performances are verified for various cases in the above manners.

1) $(515, 677, 453, 755, 551, 717)_8$: $c_{38}=6$ (NO=7)
2) $(545, 773, 557, 651, 455, 747)_8$: $c_{38}=6$ (NO=8)

Further, to search for a symbol deleting pattern used for the three-carrier system, various symbol deleting matrixes are considered for the situation where one carrier is damaged, i.e., where the R=1/6 convolutional codes change to R=1/4 convolutional codes. The reason for searching for the symbol deleting matrix pattern is the same as described for the R=1/3 convolutional codes. The following matrixes can be used as a symbol deleting matrix pattern for a method of distributing symbols for R=1/6 convolutional codes.

$$D_1 = \begin{bmatrix} 0 & 1 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix} \qquad D_2 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

$$D_3 = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} \qquad D_4 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$$

$$D_5 = \begin{bmatrix} 0 & 1 & 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 \end{bmatrix} \quad D_6 = \begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 1 \end{bmatrix}$$

$$D_7 = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix} \quad D_8 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

$$D_9 = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 \end{bmatrix} \quad D_{10} = \begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 \end{bmatrix}$$

$$D_{11} = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 \end{bmatrix} \quad D_{12} = \begin{bmatrix} 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 & 1 & 1 \end{bmatrix}$$

Taking into consideration the case where two carriers are damaged in the

three-carrier system, the following symbol deleting matrix pattern can be used in a method of distributing symbols for R=1/2 symbol-deleted convolutional codes using generator polynomials for the R=1/6 convolutional codes with a good decoding performance.

$$D_{2\text{-}1} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} \qquad D_{2\text{-}2} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

$$D_{2\text{-}3} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad D_{2\text{-}4} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

$$D_{2\text{-}5} = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \end{bmatrix} \qquad D_{2\text{-}6} = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

$$D_{2\text{-}7} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix} \qquad D_{2\text{-}8} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$D_{2\text{-}9} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix} \quad D_{2\text{-}10} = \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$D_{2\text{-}11} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad D_{2\text{-}12} = \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix}$$

Turning to FIG. 6, there is shown the convolutional encoder 601 and the symbol distributer 602 according to an embodiment of the present invention. In the exemplary embodiment, the convolutional encoder 601 has a coding rate of R=1/6 and uses generator polynomials of (545, 773, 557, 651, 455, 747). The detailed structure of the R=1/6 convolutional is illustrated in FIG. 7.

Referring to FIG. 7, upon receipt of input data, delays 711-A to 711-H delay the input data bits sequentially. During the sequential delay of the input data bits, exclusive OR gates 721-A to 721-F output coded symbols. The coded symbols of FIG. 7 are provided to the symbol distributer 602 having the structure of FIG. 8.

Referring to FIG. 8, the symbol distributer 602 is implemented by switches 811-A and 811-B. In FIG. 8, when a symbol rate of a clock for controlling the switches 811-A and 811-B is over six times a symbol rate of the symbol distributer 602, the symbols can be distributed without symbol loss. That is, the switch 811-A

sequentially receives input symbols g_1, g_2, g_3, g_4, g_5, g_6, g_1, g_2, g_3, ..., and the switch 811-B distributes the input symbols to output nodes c_1, c_2, c_3, c_4, c_5 and c_6.

FIG. 9 illustrates a transmission scheme including the channel encoder 601 and the symbol distributer 602 of FIG. 6.

Referring to FIG. 9, first to fourth CRC generators 911-914 add CRC data in a specified number of bits to input data. Specifically, 12-bit CRC is added to the 172-bit data of the first rate; 8-bit CRC is added to the 80-bit data of the second rate; 6-bit CRC is added to the 40-bit data of the third rate; and 6-bit CRC is added to the 16-bit data of the fourth rate. First to fourth tail bit generators 921-924 add 8 tail bits to the CRC-added data. Therefore, the first tail bit generator 921 outputs 192 bits; the second tail bit generator 922 outputs 96 bits; the third tail bit generator 923 outputs 54 bits; and the fourth tail bit generator 924 outputs 30 bits.

First to fourth encoders 931-934 encode data output from the first to fourth tail bit generators 921-924, respectively. Here, a K=9, R=1/6 convolutional encoder can be used for the encoders 931-934. In this case, the first encoder 931 encodes the 192-bit data output from the first tail bit generator 921 into 1152 symbols of full rate; the second encoder 932 encodes the 96-bit data output from the second tail bit generator 922 into 576 symbols of 1/2 rate; the third encoder 933 encodes the 54-bit data output from the third tail bit generator 923 into 324 symbols of about 1/4 rate; and the fourth encoder 934 encodes the 30-bit data output from the fourth tail bit generator 924 into 180 symbols of about 1/8 rate.

First to fourth symbol distributers 941-944 distribute the symbols output from the encoders 931-934, respectively. Here, for symbol distribution, a channel controller (not shown) generates control signals for distributing the channel coded

bits such that the performance degradation may be minimized during decoding of received damaged bits, when the coded symbols are transmitted being overlaid on the symbols of a different system at the same frequency band. The symbol distributers 941-944 then assign the symbols output from the encoders 931-934 to the corresponding carriers according to the control signals, respectively.

Rate matchers 951-953 each include a symbol repeater and a symbol deletion device. The rate matchers 951-953 match rates of the symbols output from the corresponding symbol distributers 942-944 to a rate of the symbols output from the symbol distributer 941. First to fourth channel interleavers 961-964 interleave the symbols output from the symbol distributer 941 and the rate matchers 951-953, respectively.

For the DS-CDMA communication system, the symbol distributers 941-944 of FIG. 9 can be removed.

As described above, in the multicarrier system employing the frequency overlay method, the respective carriers have limited transmission powers according to the loading in the frequency bands of the existing IS-95 system, which results in loss of data received at one or more carrier frequency bands. To solve this problem, by using the generator polynomials for the channel encoder and a symbol distribution method, it is possible to provide a high coding gain against the data loss due to the carrier loss, thereby preventing degradation of the BER.

While the invention has been shown and described with reference to a certain preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A channel transmission device for a code division multiple access (CDMA) communication system using at least two carriers, comprising:

a channel encoder for encoding channel data to be transmitted into symbols at a predetermined coding rate;

a channel controller for generating a symbol distribution signal according to a predetermined symbol deleting matrix pattern, wherein the symbol deleting matrix pattern is so determined as to distribute the symbols to the respective carriers with a minimized performance degradation even though a specific carrier is damaged; and

a symbol distributer for receiving the symbols and distributing received symbols to the carriers according to the symbol distribution signal.

2. The channel transmission device as claimed in claim 1, wherein the channel encoder is a convolutional encoder with a coding rate of R=1/6.

3. The channel transmission device as claimed in claim 2, wherein the convolutional encoder generates the symbols using one of generator polynomials in a following table,

No	1/6 Generator Polynomial (Octal Number)	1/6 BER coeff. c_{37}, c_{38}, c_{39}	1/2 BER coeff. c_{12} (1,2; 3,4; 5,6)	1/4 BER coeff. c_{24} (1234;1256;3456)
1	457 755 551 637 523 727	-149	-405268	-825
2	557 751 455 763 625 727	-149	-405268	-825
3	457 755 551 637 625 727	-149	-405268	-865

4	557 751 455 763 523 727	-149	-405268	-865
5	457 755 455 763 625 727	-149	-405268	-1465
6	557 751 551 637 523 727	-149	-405268	-1465
7	515 677 453 755 551 717	-169	-384050	-421
8	545 773 557 651 455 747	-169	-384050	-421
9	515 677 557 651 551 717	-1612	-384050	-421
10	545 773 453 755 455 747	-1612	-384050	-421
11	515 677 557 651 455 747	-1612	-384050	-481
12	545 773 453 755 551 717	-1612	-384050	-481
13	457 755 465 753 551 637	-1612	-405252	-685
14	457 755 531 657 551 637	-1612	-405252	-685
15	557 751 455 763 465 753	-1612	-405252	-865
16	557 751 455 763 531 657	-1612	-405252	-865
17	557 751 465 753 551 637	-1612	-405252	-6145
18	557 751 531 657 551 637	-1612	-405252	-6145
19	457 755 455 763 465 753	-1612	-405252	-1465
20	457 755 455 763 531 657	-1612	-405252	-1465
21	557 751 455 763 515 567	-169	-4052123	-861
22	457 755 551 637 545 735	-169	-4052123	-861
23	457 755 551 637 515 567	-169	-4052123	-881

24	557 751 455 763 545 735	-169	-4052123	-881
25	557 751 551 637 515 567	-169	-4052123	-1461
26	457 755 455 763 545 735	-169	-4052123	-1461
27	515 677 551 717 531 657	-186	-385052	-264
28	545 773 455 747 465 753	-186	-385052	-264
29	515 677 455 747 531 657	-186	-385052	-864
30	545 773 551 717 465 753	-186	-385052	-864
31	453 755 557 751 455 747	-11015	-404050	-416
32	457 755 557 651 551 717	-11015	-404050	-461
33	453 755 557 751 551 717	-11015	-404050	-4112
34	457 755 557 651 455 747	-11015	-404050	-4111
35	453 755 457 755 551 717	-11015	-404050	-1416
36	557 651 557 751 455 747	-11015	-404050	-1416
37	457 755 551 637 557 625	-1109	-405268	-8211
38	557 751 455 763 523 755	-1109	-405268	-8211
39	457 755 455 763 523 727	-1109	-405268	-1425
40	457 755 455 763 557 625	-1109	-405268	-1425
41	557 751 551 637 523 755	-1109	-405268	-1425
42	557 751 551 637 625 727	-1109	-405268	-1425
43	457 755 551 637 523 755	-1109	-405268	-8145

44	557 751 455 763 557 625	-1109	-405268	-8145
45	545 773 455 763 515 567	-1106	-3852123	-861
46	545 773 551 637 515 567	-1106	-3852123	-861
47	515 677 455 763 545 735	-1106	-3852123	-861
48	515 677 551 637 545 735	-1106	-3852123	-861
49	515 677 551 637 515 567	-1106	-3852123	-8181
50	545 773 455 763 545 735	-1106	-3852123	-8181
51	545 773 557 651 551 717	-1129	-384050	-481
52	515 677 453 755 455 747	-1129	-384050	-481
53	457 755 455 763 515 567	-1129	-4052123	-1481
54	557 751 551 637 545 735	-1129	-4052123	-1481
55	515 677 455 763 515 567	-1166	-3852123	-8181
56	545 773 551 637 545 735	-1166	-3852123	-8181
57	453 755 457 755 455 747	-12015	-404050	-1412
58	557 651 557 751 551 717	-12015	-404050	-1412

4. The channel transmission device as claimed in claim 1, wherien the symbol distributer comprises:

a first selector for sequentially multiplexing the received symbols; and

a second selector for distributing the multiplexed symbols to the carriers according to the symbol distribution signal.

5. A channel transmission device for a multicarrier CDMA communication system using at least two carriers, comprising:

a channel encoder for encoding channel data to be transmitted into symbols at a predetermined coding rate;

a symbol distributer for receiving the symbols and distributing received symbols to the carriers according to a predetermined symbol deleting matrix pattern, wherein the symbol deleting matrix pattern is so determined as to distribute the symbols to the respective carriers with a minimized performance degradation even though a specific carrier is damaged;

a channel interleaver for channel interleaving the distributed symbols;

a demultiplexer for distributing the interleaved symbols to the carriers;

a plurality of orthogonal modulators for generating orthogonally modulated signals by multiplying the distributed symbols by orthogonal codes for the corresponding channels;

a plurality of spreaders for receiving the orthogonally modulated signals and generating spread signals by multiplying the received orthogonally modulated signals by a spreading code; and

a plurality of transmitters for receiving the spread signals and transmitting the received spread signals using the carriers.

6. The channel transmission device as claimed in claim 5, wherein the channel encoder is a convolutional encoder with a coding rate of R=1/6.

7. The channel transmission device as claimed in claim 6, wherein the convolutional encoder generates the symbols using one of generator polynomials in a following table,

No	1/6 Generator Polynomial (Octal Number)	1/6 BER coeff. c_{37}, c_{38}, c_{39}	1/2 BER coeff. c_{12} (1,2; 3,4; 5,6)	1/4 BER coeff. c_{24} (1234;1256;3456)
1	457 755 551 637 523 727	-149	-405268	-825
2	557 751 455 763 625 727	-149	-405268	-825
3	457 755 551 637 625 727	-149	-405268	-865
4	557 751 455 763 523 727	-149	-405268	-865
5	457 755 455 763 625 727	-149	-405268	-1465
6	557 751 551 637 523 727	-149	-405268	-1465
7	515 677 453 755 551 717	-169	-384050	-421
8	545 773 557 651 455 747	-169	-384050	-421
9	515 677 557 651 551 717	-1612	-384050	-421
10	545 773 453 755 455 747	-1612	-384050	-421
11	515 677 557 651 455 747	-1612	-384050	-481
12	545 773 453 755 551 717	-1612	-384050	-481
13	457 755 465 753 551 637	-1612	-405252	-685
14	457 755 531 657 551 637	-1612	-405252	-685
15	557 751 455 763 465 753	-1612	-405252	-865
16	557 751 455 763 531 657	-1612	-405252	-865
17	557 751 465 753 551 637	-1612	-405252	-6145
18	557 751 531 657 551 637	-1612	-405252	-6145

19	457 755 455 763 465 753	-1612	-405252	-1465
20	457 755 455 763 531 657	-1612	-405252	-1465
21	557 751 455 763 515 567	-169	-4052123	-861
22	457 755 551 637 545 735	-169	-4052123	-861
23	457 755 551 637 515 567	-169	-4052123	-881
24	557 751 455 763 545 735	-169	-4052123	-881
25	557 751 551 637 515 567	-169	-4052123	-1461
26	457 755 455 763 545 735	-169	-4052123	-1461
27	515 677 551 717 531 657	-186	-385052	-264
28	545 773 455 747 465 753	-186	-385052	-264
29	515 677 455 747 531 657	-186	-385052	-864
30	545 773 551 717 465 753	-186	-385052	-864
31	453 755 557 751 455 747	-11015	-404050	-416
32	457 755 557 651 551 717	-11015	-404050	-461
33	453 755 557 751 551 717	-11015	-404050	-4112
34	457 755 557 651 455 747	-11015	-404050	-4111
35	453 755 457 755 551 717	-11015	-404050	-1416
36	557 651 557 751 455 747	-11015	-404050	-1416
37	457 755 551 637 557 625	-1109	-405268	-8211
38	557 751 455 763 523 755	-1109	-405268	-8211

39	457 755 455 763 523 727	-1109	-405268	-1425
40	457 755 455 763 557 625	-1109	-405268	-1425
41	557 751 551 637 523 755	-1109	-405268	-1425
42	557 751 551 637 625 727	-1109	-405268	-1425
43	457 755 551 637 523 755	-1109	-405268	-8145
44	557 751 455 763 557 625	-1109	-405268	-8145
45	545 773 455 763 515 567	-1106	-3852123	-861
46	545 773 551 637 515 567	-1106	-3852123	-861
47	515 677 455 763 545 735	-1106	-3852123	-861
48	515 677 551 637 545 735	-1106	-3852123	-861
49	515 677 551 637 515 567	-1106	-3852123	-8181
50	545 773 455 763 545 735	-1106	-3852123	-8181
51	545 773 557 651 551 717	-1129	-384050	-481
52	515 677 453 755 455 747	-1129	-384050	-481
53	457 755 455 763 515 567	-1129	-4052123	-1481
54	557 751 551 637 545 735	-1129	-4052123	-1481
55	515 677 455 763 515 567	-1166	-3852123	-8181
56	545 773 551 637 545 735	-1166	-3852123	-8181
57	453 755 457 755 455 747	-12015	-404050	-1412
58	557 651 557 751 551 717	-12015	-404050	-1412

8. The channel transmission device as claimed in claim 5, wherein the symbol distributer comprises:

a first selector for sequentially multiplexing the received symbols; and

a second selector for distributing the multiplexed symbols to the carriers according to the symbol distribution signal.

9. A channel transmission method for a CDMA communication system using at least two carriers, comprising the steps of:

encoding channel data to be transmitted into symbols at a predetermined coding rate; and

receiving the symbols and distributing received symbols to the carriers according to a predetermined symbol deleting matrix pattern, wherein the symbol deleting matrix pattern is so determined as to distribute the symbols to the respective carriers with a minimized performance degradation even though a specific carrier is damaged.

10. The channel transmission method as claimed in claim 9, wherein the channel encoder is a convolutional encoder with a coding rate of R=1/6.

11. The channel transmission method as claimed in claim 9, the symbol distribution step comprises the steps of:

sequentially multiplexing the received symbols; and

distributing the multiplexed symbols to the carriers according to the symbol distribution signal.

12. A channel encoding device comprising:

a plurality of delays for delaying an input data bit to generate first to eight delayed data bits;

a first operator for exclusively ORing the input data bit and the third, fifth, sixth, seventh and eighth delayed data bits to generate a first symbol;

a second operator for exclusively ORing the input data bit and the first, second, third, fifth, sixth and eighth delayed data bits to generate a second symbol;

a third operator for exclusively ORing the input data bit and the second, third, fifth and eighth delayed data bits to generate a third symbol;

a fourth operator for exclusively ORing the input data bit and the first, fourth, fifth, sixth, seventh and eighth delayed data bits to generate a fourth symbol;

a fifth operator for exclusively ORing the input data bit and the first, fourth, sixth and eighth delayed data bits to generate a fifth symbol; and

a sixth operator for exclusively ORing the input data bit and the first, second, fourth, sixth, seventh and eighth delayed data bits to generate a sixth symbol.

13. A channel transmission device for a CDMA communication system, comprising:

a channel encoder including,

a plurality of delays for delaying an input data bit to generate first to eight delayed data bits;

a first operator for exclusively ORing the input data bit and the third, fifth, sixth, seventh and eighth delayed data bits to generate a first symbol;

a second operator for exclusively ORing the input data bit and the first, second, third, fifth, sixth and eighth delayed data bits to generate a second symbol;

a third operator for exclusively ORing the input data bit and the second, third, fifth and eighth delayed data bits to generate a third symbol;

a fourth operator for exclusively ORing the input data bit and the first, fourth, fifth, sixth, seventh and eighth delayed data bits to generate a fourth symbol;

a fifth operator for exclusively ORing the input data bit and the first,

fourth, sixth and eighth delayed data bits to generate a fifth symbol;

a sixth operator for exclusively ORing the input data bit and the first, second, fourth, sixth, seventh and eighth delayed data bits to generate a sixth symbol;

a channel interleaver for receiving the symbols and channel interleaving the received symbols;

an orthogonal modulator for generating an orthogonally modulated signal by multiplying the distributed symbols by an orthogonal code for the channel; and

a spreader for generating a spread signal by multiplying the orthogonally modulated signal by a spreading code.

14. The channel transmission device as claimed in claim 13,wherein the symbol distributer distributes the symbols output from the channel encoder according to a symbol deleting matrix pattern, wherein the symbol deleting matrix pattern is so determined as to distribute the symbols to the respective carriers with a minimized performance degradation even though a specific carrier is damaged.

15. A channel encoding method for a CDMA communication system, comprising the steps of:

shiftingly delaying an input data bit to generate first to eight delayed data bits;

exclusively ORing the input data bit and the third, fifth, sixth, seventh and eighth delayed data bits to generate a first symbol;

exclusively ORing the input data bit and the first, second, third, fifth, sixth and eighth delayed data bits to generate a second symbol;

exclusively ORing the input data bit and the second, third, fifth and eighth delayed data bits to generate a third symbol;

exclusively ORing the input data bit and the first, fourth, fifth, sixth, seventh

and eighth delayed data bits to generate a fourth symbol;

exclusively ORing the input data bit and the first, fourth, sixth and eighth delayed data bits to generate a fifth symbol; and

exclusively ORing the input data bit and the first, second, fourth, sixth, seventh and eighth delayed data bits to generate a sixth symbol.

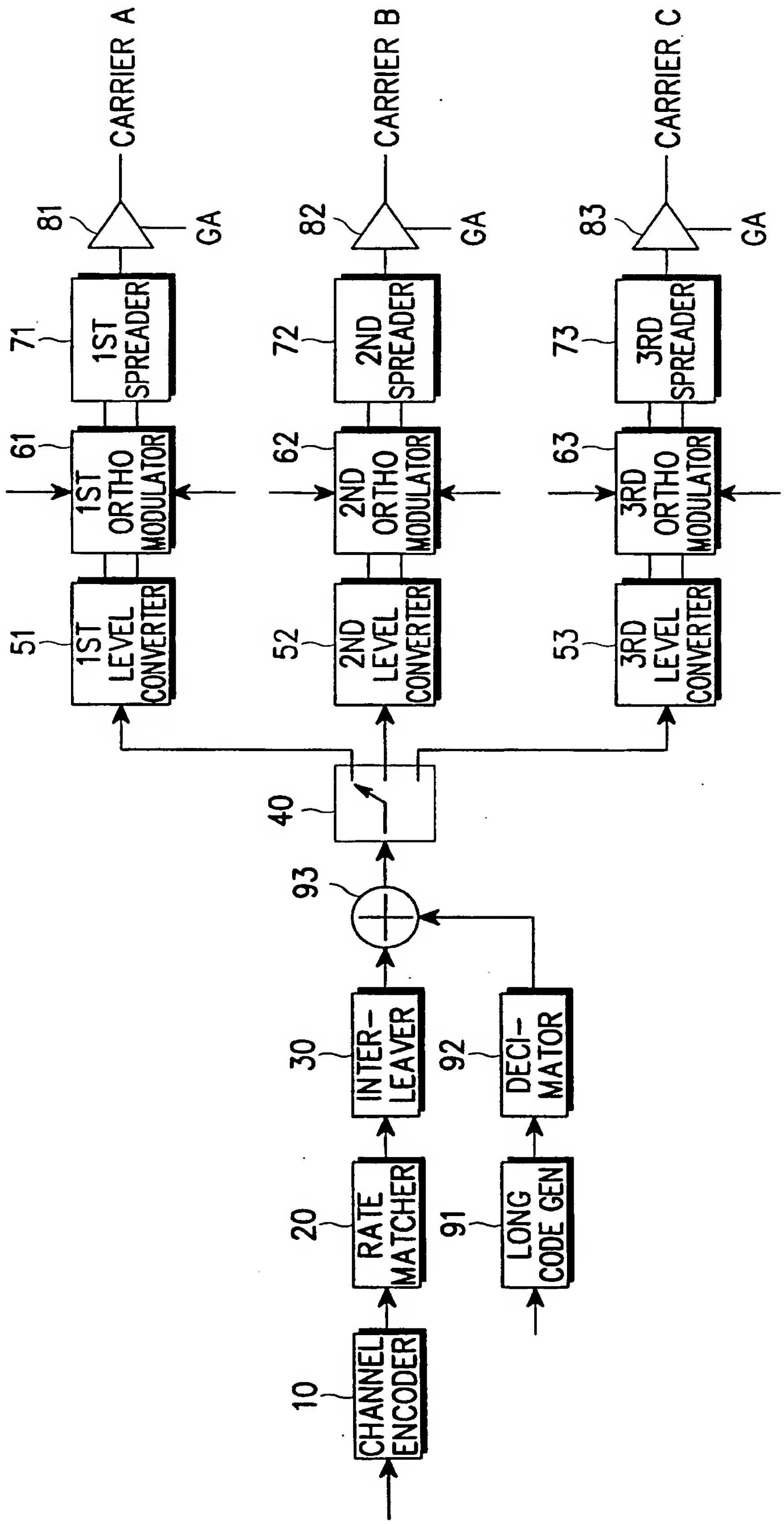

CHANNEL ENCODER
10
RATE MATCHER
20
INTER-LEAVER
30
LONG CODE GEN
91
DECI-MATOR
92
93
40
1ST LEVEL CONVERTER
51
2ND LEVEL CONVERTER
52
3RD LEVEL CONVERTER
53
1ST ORTHO MODULATOR
61
2ND ORTHO MODULATOR
62
3RD ORTHO MODULATOR
63
1ST SPREADER
71
2ND SPREADER
72
3RD SPREADER
73
81
82
83
GA
GA
GA
CARRIER A
CARRIER B
CARRIER C

FIG. 1

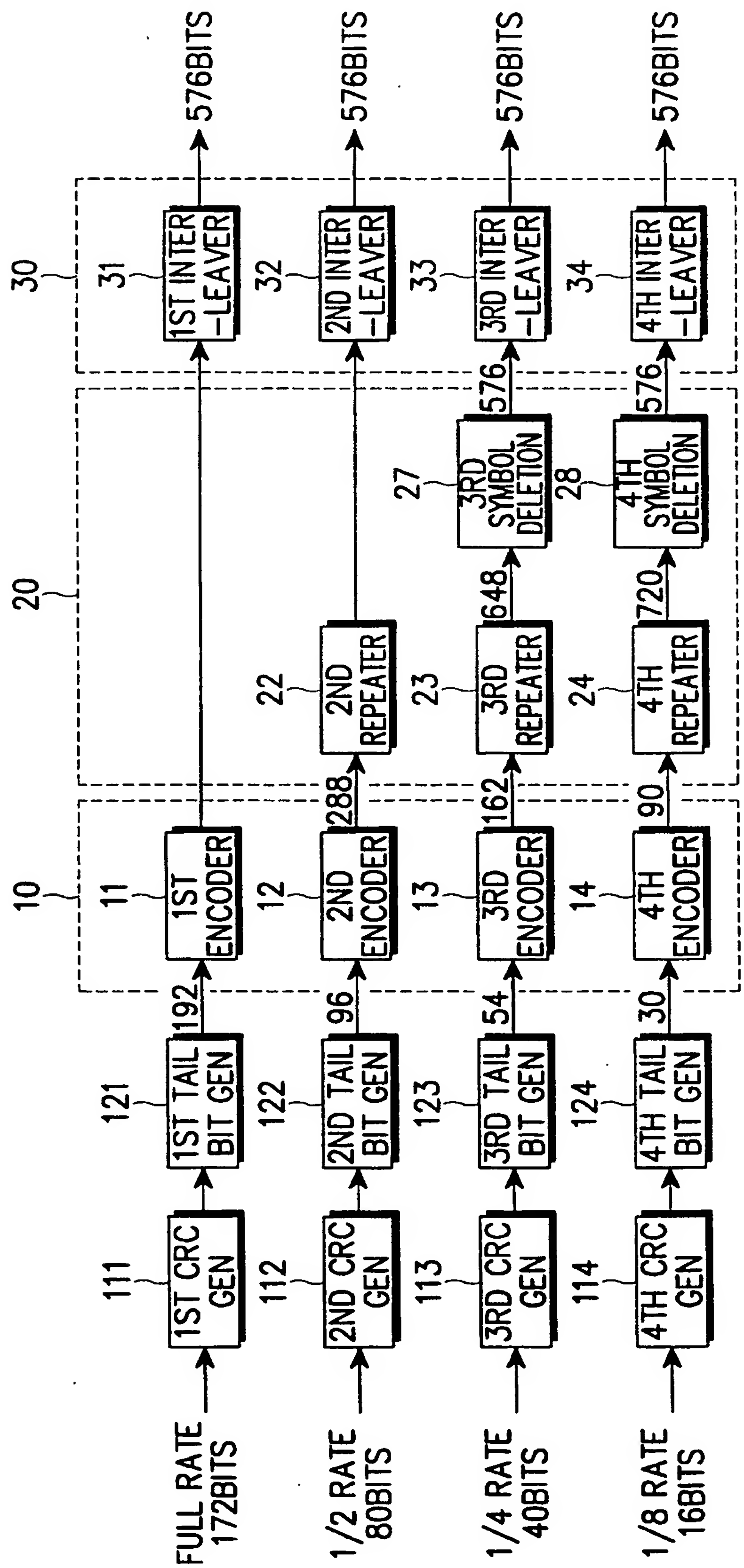

FULL RATE 172BITS
1/2 RATE 80BITS
1/4 RATE 40BITS
1/8 RATE 16BITS
111
1ST CRC GEN
112
2ND CRC GEN
113
3RD CRC GEN
114
4TH CRC GEN
121
1ST TAIL BIT GEN
122
2ND TAIL BIT GEN
123
3RD TAIL BIT GEN
124
4TH TAIL BIT GEN
192
96
54
30
10
11
1ST ENCODER
12
2ND ENCODER
13
3RD ENCODER
14
4TH ENCODER
288
162
90
20
22
2ND REPEATER
23
3RD REPEATER
24
4TH REPEATER
648
720
27
3RD SYMBOL DELETION
28
4TH SYMBOL DELETION
576
576
30
31
1ST INTER -LEAVER
32
2ND INTER -LEAVER
33
3RD INTER -LEAVER
34
4TH INTER -LEAVER
576BITS
576BITS
576BITS
576BITS

FIG. 2

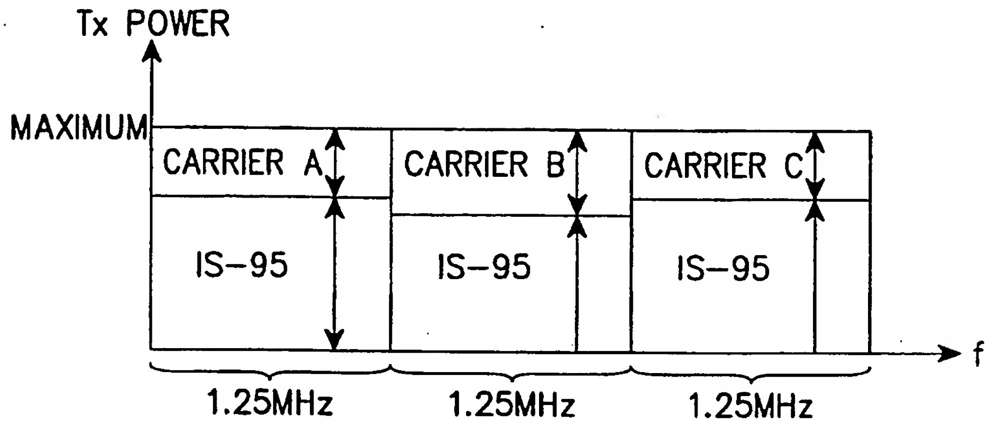

Tx POWER
MAXIMUM
CARRIER A
CARRIER B
CARRIER C
IS-95
IS-95
IS-95
f
1.25MHz
1.25MHz
1.25MHz

FIG. 3

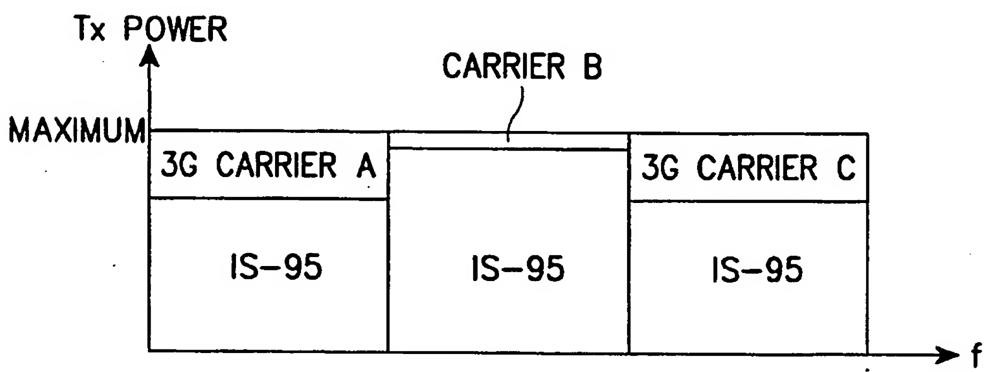

Tx POWER
CARRIER B
MAXIMUM
3G CARRIER A
3G CARRIER C
IS-95
IS-95
IS-95
f

FIG. 4

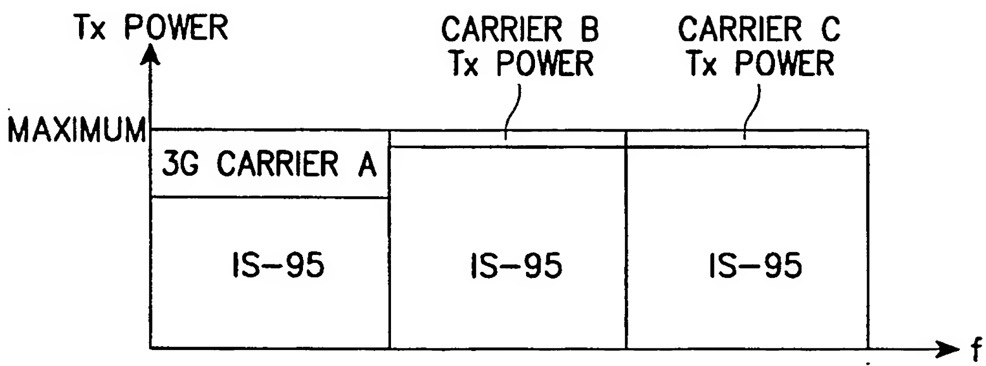

Tx POWER
CARRIER B
Tx POWER
CARRIER C
Tx POWER
MAXIMUM
3G CARRIER A
IS-95
IS-95
IS-95
f

FIG. 5

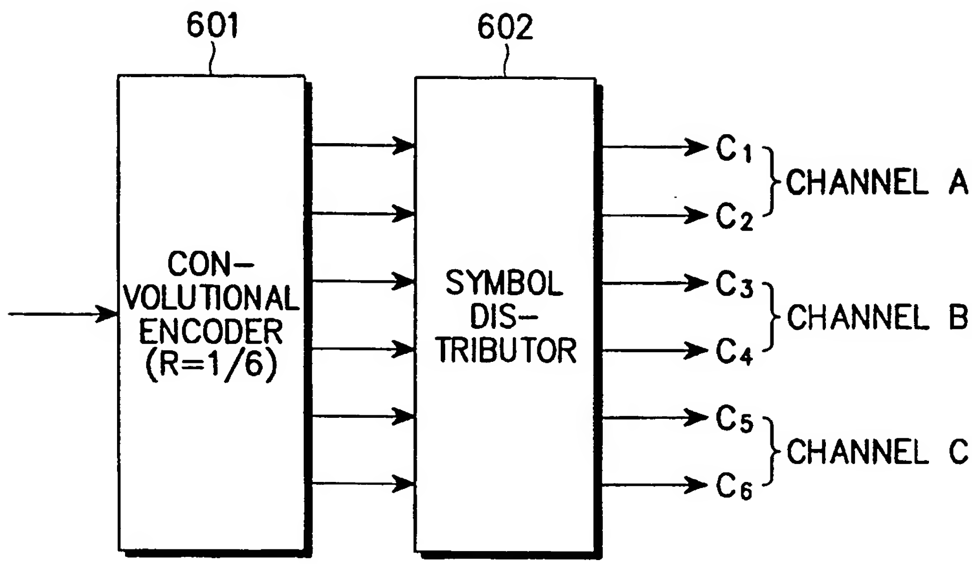
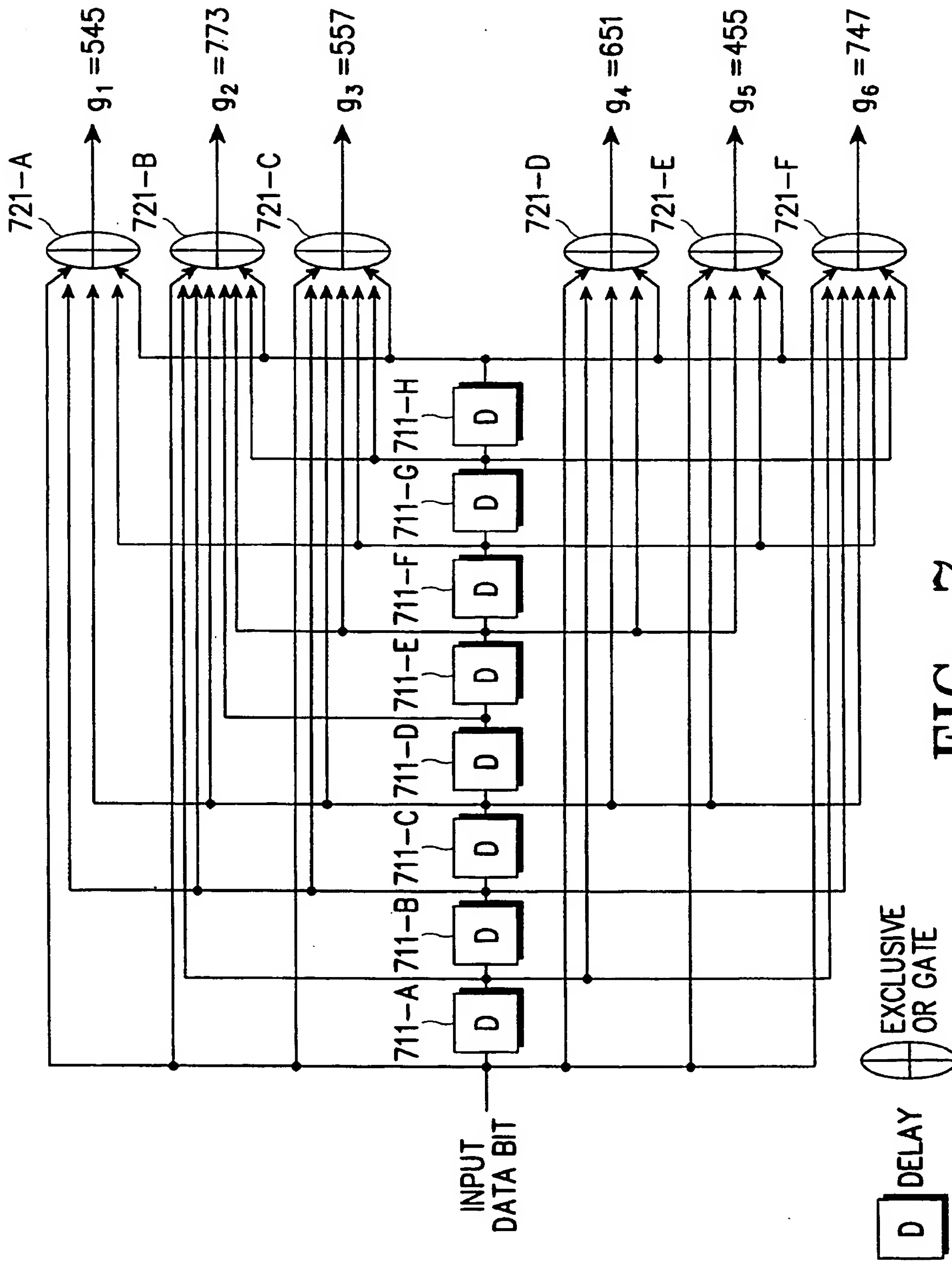

601
602
CON-
VOLUTIONAL
ENCODER
(R=1/6)
SYMBOL
DIS-
TRIBUTOR
C1
C2
CHANNEL A
C3
C4
CHANNEL B
C5
C6
CHANNEL C

FIG. 6



g_1 =545
g_2 =773
g_3 =557
g_4 =651
g_5 =455
g_6 =747
721-A
721-B
721-C
721-D
721-E
721-F
711-A
711-B
711-C
711-D
711-E
711-F
711-G
711-H
INPUT DATA BIT
D DELAY
EXCLUSIVE OR GATE

FIG. 7

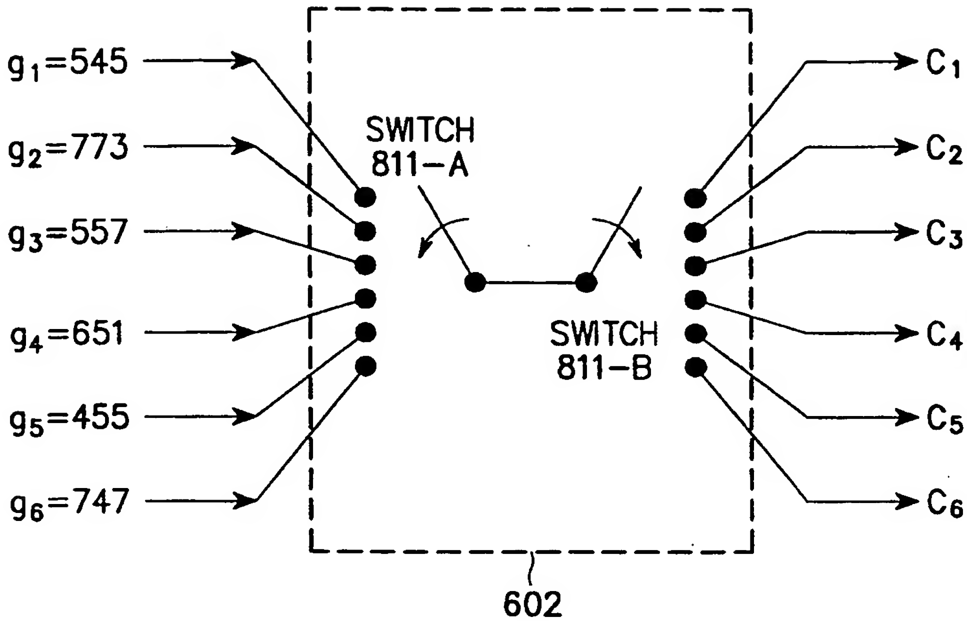

g_1=545
g_2=773
g_3=557
g_4=651
g_5=455
g_6=747
SWITCH 811-A
SWITCH 811-B
C_1
C_2
C_3
C_4
C_5
C_6
602

FIG. 8

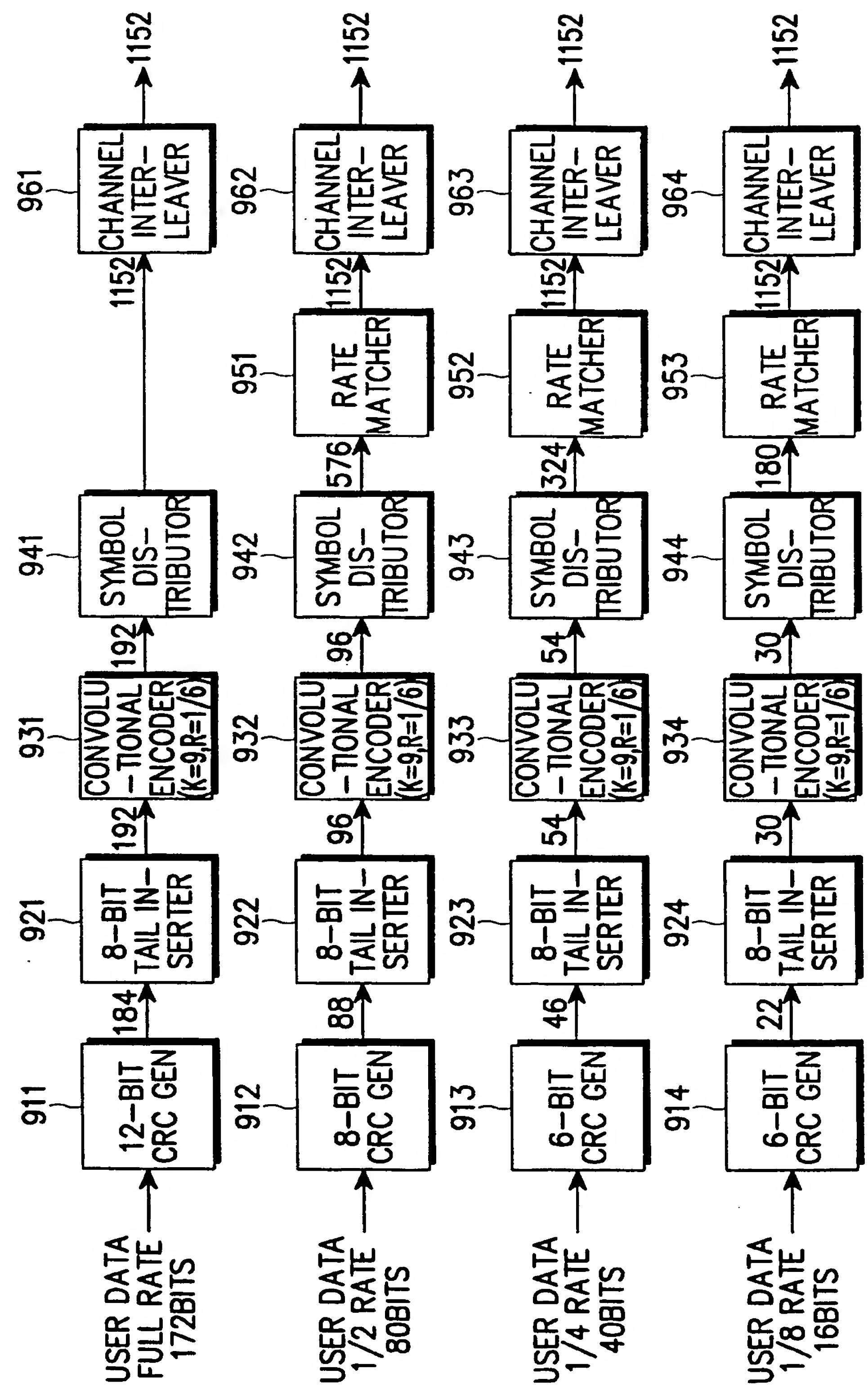

USER DATA FULL RATE 172BITS
USER DATA 1/2 RATE 80BITS
USER DATA 1/4 RATE 40BITS
USER DATA 1/8 RATE 16BITS
911
12-BIT CRC GEN
912
8-BIT CRC GEN
913
6-BIT CRC GEN
914
6-BIT CRC GEN
184
88
46
22
921
922
923
924
8-BIT TAIL IN-SERTER
192
96
54
30
931
932
933
934
CONVOLU-TIONAL ENCODER (K=9,R=1/6)
941
942
943
944
SYMBOL DIS-TRIBUTOR
576
324
180
951
952
953
RATE MATCHER
1152
961
962
963
964
CHANNEL INTER-LEAVER

FIG. 9

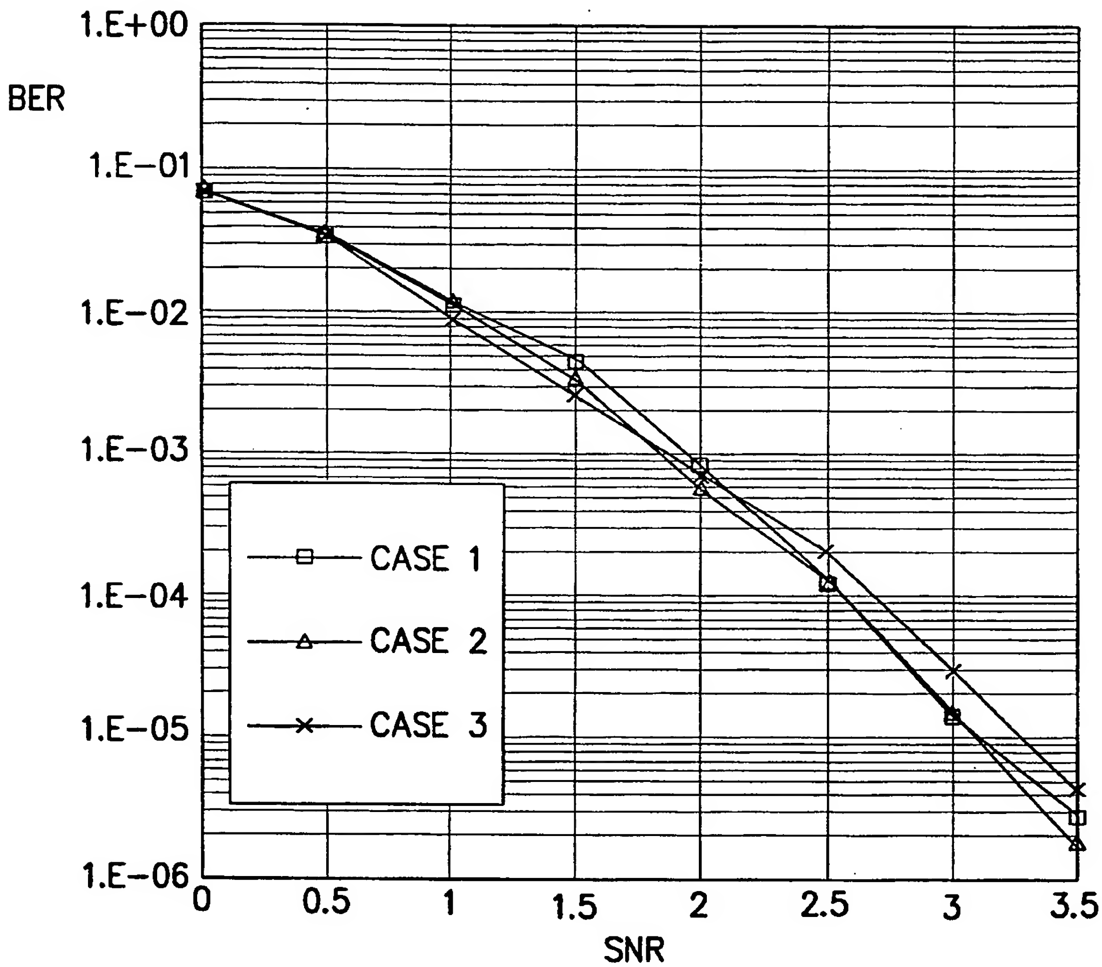
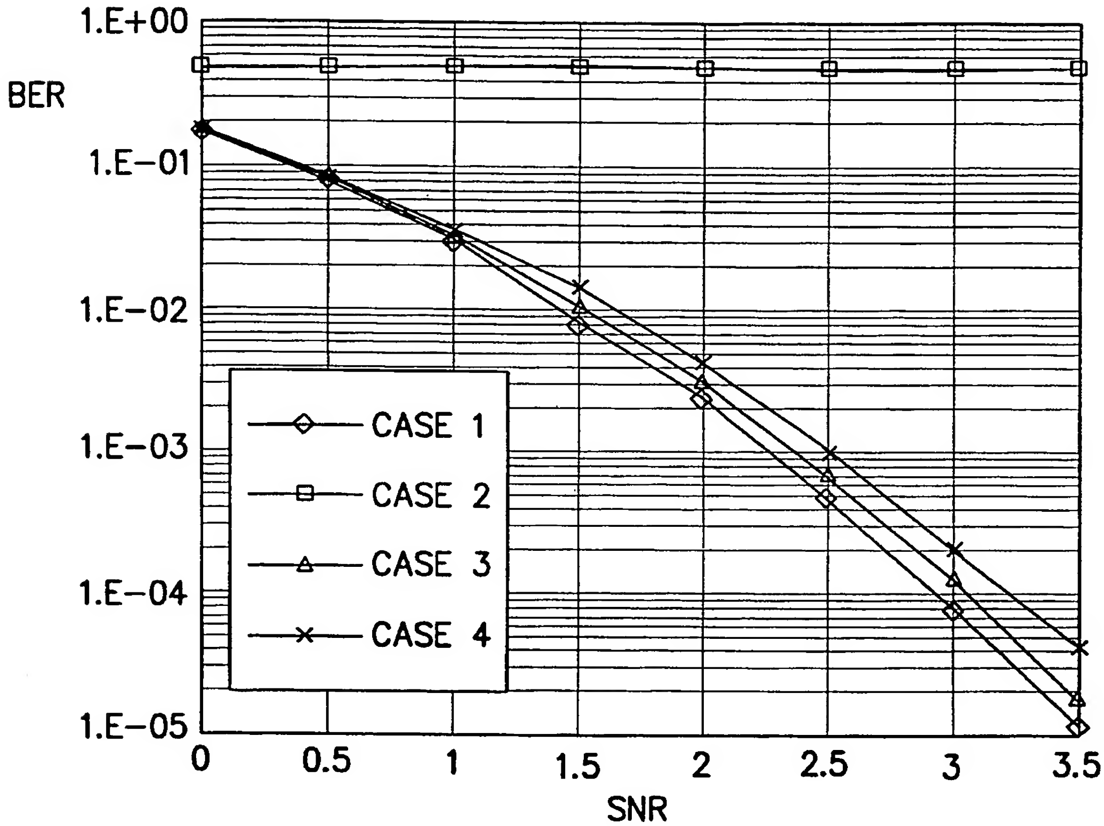

1.E+00
BER
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
0
0.5
1
1.5
2
2.5
3
3.5
SNR
CASE 1
CASE 2
CASE 3

FIG. 10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1.E-04
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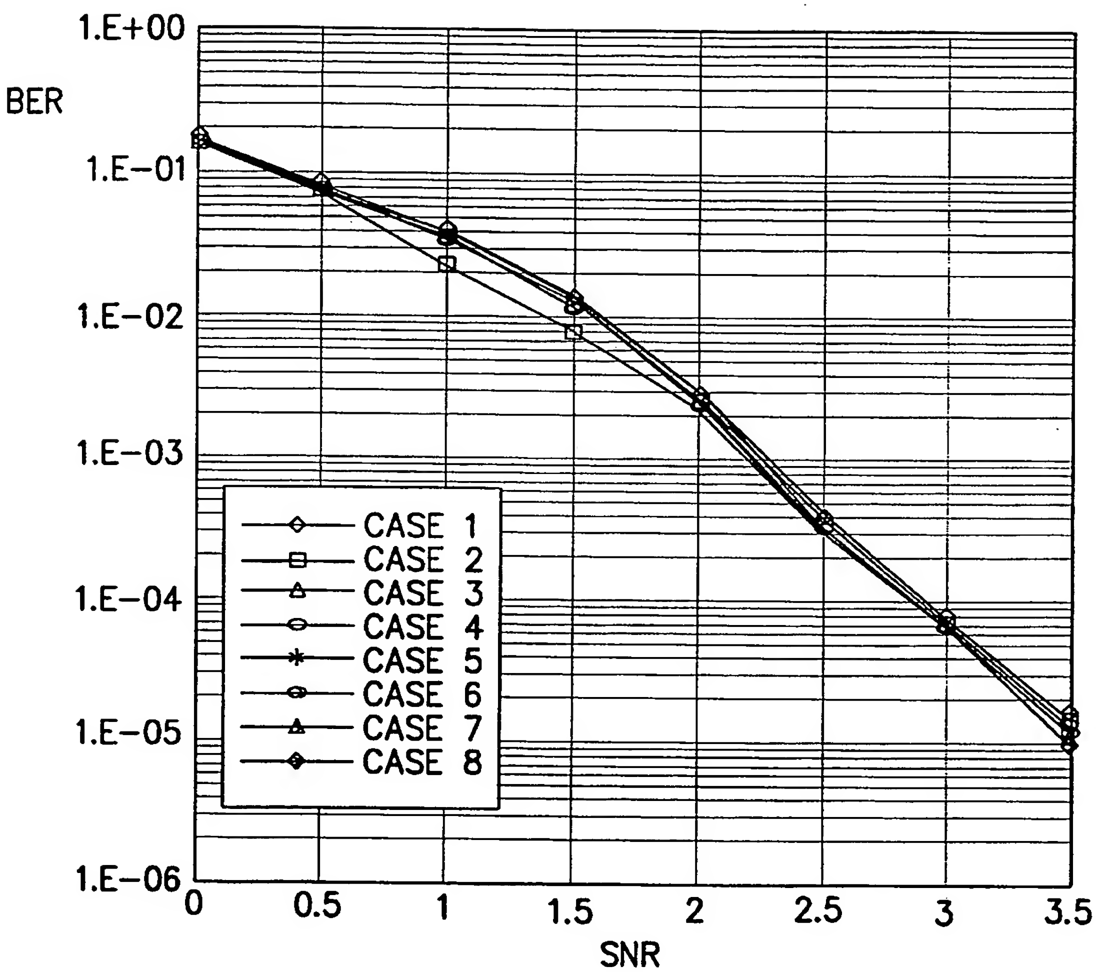
3
3.5
SNR
CASE 1
CASE 2
CASE 3
CASE 4

FIG. 11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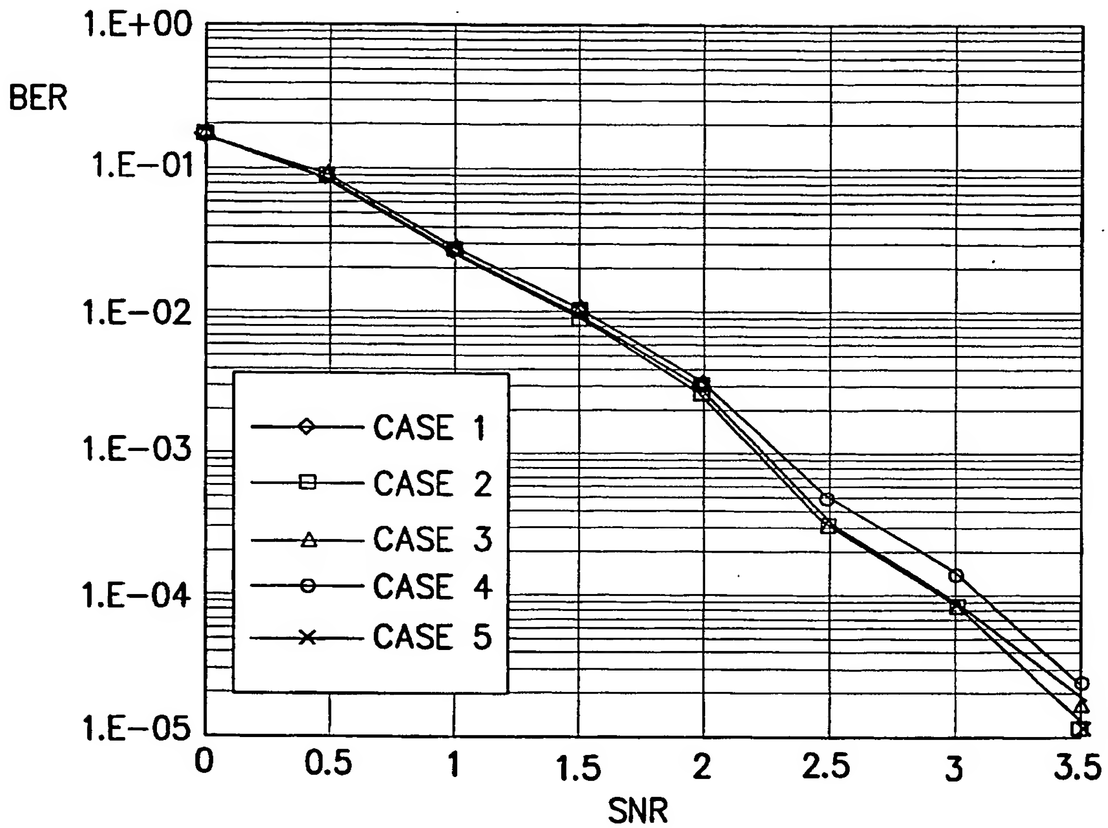
SNR
CASE 1
CASE 2
CASE 3
CASE 4
CASE 5
CASE 6
CASE 7
CASE 8

FIG. 12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3
3.5
SNR
CASE 1
CASE 2
CASE 3
CASE 4
CASE 5

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 99/00267

A. CLASSIFICATION OF SUBJECT MATTER

IPC[6]: H04J 13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC[6]: H03M; H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 196 25 054 A1 (TELEKOM) 2 January 1998 (02.01.98) fig. 3a, 3b; abstract; page 4, line 57 - page 6, line 40.	12-15
A		1,5,9
X	EP 0750 401 A2 (MOTOROLA) 27 December 1996 (27.12.96) fig. 1; col. 3, lines 34-38, col. 4, lines 1-12, col. 6, lines 7-11.	12,13,15
A		1-3,5-7
X	JP 63-15534 A (NEC). Patents Abstract of Japan, Vol. 12, No. 221 (E-625), 1988.06.23 (abstract). --	12,13,15
Y	EP 0 680 158 A1 (AT&T) 2 November 1995 (02.11.95) fig. 3,6,10; col. 6, line 46 - col. 8, line 8, col. 13, line 15 - col. 14, line 16, col. 16, line 16 - col. 17, line 11.	1,5,9
A		2-4,6-8,10,11

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
„A“ document defining the general state of the art which is not considered to be of particular relevance
„E“ earlier application or patent but published on or after the international filing date
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„O“ document referring to an oral disclosure, use, exhibition or other means
„P“ document published prior to the international filing date but later than the priority date claimed
„T“ later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
„X“ document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
„Y“ document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
„&“ document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 1999 (29.10.99)	12 November 1999 (12.11.99)

Name and mailing adress of the ISA/AT	Authorized officer
Austrian Patent Office Kohlmarkt 8-10; A-1014 Vienna Facsimile No. 1/53424/200	Mesa Telephone No. 1/53424/327

INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 99/00267

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 95/22818 A (MOTOROLA) 24 August 1995 (24.08.95) figs.; abstract; page 5, lines 11-14, page 5, line 29 - page 6, line 2, page 6, lines 9-28, page 9, line 30 - page 10, line 16, page 11, line 31 - page 12, line 10, page 12, line 27 - page 13, line 15; claims 1,2.	1,5,9
A		2-4,6-8,10-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/KR 99/00267

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		CA AA 2145566	30-10-1995
		EP A1 680157	02-11-1995
		US A 5799013	25-08-1998
WO A 022818		keine - none - rien	